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Control of DO Concentration using PID and Fuzzy Controllers

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Abstract—*Aeration tanks play a vital role in Water treatment plant and the Dissolved Oxygen concentration is an important parameter for their proper functioning. The continuous stirred tank reactor (CSTR) that may be considered as the basic model for aeration tanks requires modeling and control. In this paper, an adiabatic process with 3 aeration tanks in series is considered similar to the BSM1 sludge process and comparison of DO concentration control using PID and Fuzzy logic control is illustrated.*

Keywords*: CSTR; sludge process;DO; PID; Fuzzy logic*

1. INTRODUCTION

Water treatment plant is an important part of any process industry for a clean and green environment. The water to be treated along with impurities enters the treatment plant at different conditions and needs to be treated with bacteria or chemicals. Activated Sludge process containing aeration tank and a clarifier performs the task of treatment. Different benchmarks are developed for such processes. Such a benchmark is the BSM1 whose block diagram is shown in figure1[1].

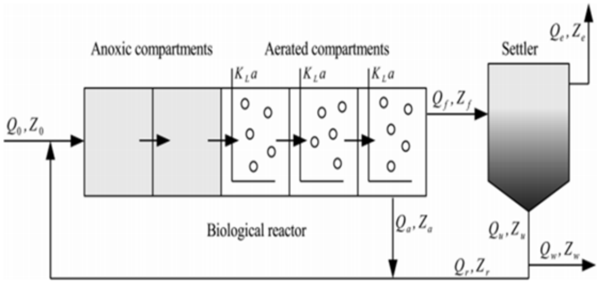

Fig. 1: BSM Model [1]

The survival of microorganisms (or reaction rate) in the aeration tank requires certain amount of oxygen with respect to the inflow rate and hence controlling these parameters like dissolved oxygen concentration, flow rate etc. is necessary for proper functioning of the plant. This motivated the study of aeration tanks in the BSM1 benchmark model which can be represented by series combination of three CSTR tanks. Also DO concentration is an important parameter for the aeration tank in Activated Sludge process. Control of concentration is done using different aeration methods such as Diffused aeration, Surface aerators and pure oxygen aeration. Oxygen deficiency or unnecessary oxygen supply may affect the microorganisms in the plant that are responsible for purification and the economical aspects of the plant. Suitable aeration equipment and a proper control technique may therefore help in the optimal DO concentration control in the process. In this paper, an adiabatic process with 3 aeration tanks of BSM1 sludge process is represented with 3 series continuous stirred tank reactor (CSTR). Modeling and comparison of outflow concentration control in the plant using PID and Fuzzy logic control is illustrated with the main objective is DO concentration control.

2. MATHEMATICAL MODEL OF THE 3 TANK SYSTEM

2.1. Model for a single tank

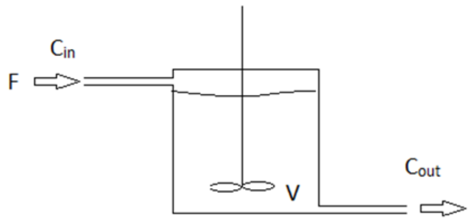

Fig. 2: CSTR tank

Fig. 2 shows a single tank CSTR and modeling of the tank is done with the assumptions that K is the reaction rate and the inflow rate, F and Volume of the tank, V remain constant. The transfer function can be obtained from the Conservation of mass equation [2]

$$V_1\frac{dC_{out}}{dt} = FC_{in} - FC_{out} - VKC_{out}$$

Rearranging the equation and taking Laplace Transform we obtain the following transfer function.

$$\frac{C_{out}(s)}{C_{in}(s)} = \frac{K}{\tau(s)+1}$$

Where K is the gain of the transfer function and $\boldsymbol{\tau}$ is the time constant for the tank

$$K = \frac{F}{F+KV}$$

$$\tau = \frac{V}{F+KV}$$

For the aeration tanks, we consider the following parameters [4] for inflow, volume and reaction rate,

F=0.0085 m^3/min

V=1.05 m^3

Reaction rate, K=0.04 /min

Therefore, the transfer function can be obtained as

$$\frac{C_{out}(s)}{C_{in}(s)} = \frac{0.669}{8.26(s)+1}$$

2.2. Model for 3 series tanks

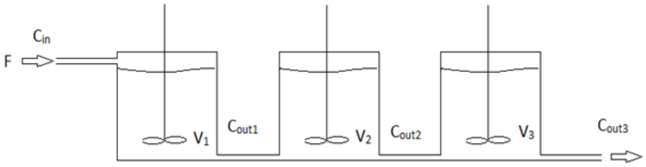

Fig. 3: CSTR tank representation of aeration tanks of BSM1 benchmark model

Modeling equation of three tanks can be obtained from the product of transfer function of three single CSTR tanks.

$$\frac{C_{out3}(s)}{C_{in}(s)} = \frac{C_{out1}(s)}{C_{in}(s)}\frac{C_{out2}(s)}{C_{out1}(s)}\frac{C_{out3}(s)}{C_{out2}(s)}$$

Assuming Inflow rate (F), Volume (V) and Reaction Rate (K) as constant for the three tanks, the transfer function of the 3-tank system can be obtained as

$$\frac{C_{out3}(s)}{C_{in}(s)} = \left[\frac{K}{\tau(s)+1}\right]\left[\frac{K}{\tau(s)+1}\right]\left[\frac{K}{\tau(s)+1}\right]$$

Substituting the values for F, V, and K the transfer function becomes

$$\frac{C_{out}(s)}{C_{in}(s)} = \left[\frac{0.669}{8.26(s)+1}\right]\left[\frac{0.669}{8.26(s)+1}\right]\left[\frac{0.669}{8.26(s)+1}\right]$$

2.3. PID And Fuzzy controller

2.3.1. PID controller model

PID controller is simple and effective and hence it is used in many process industries including water treatment plant [3]. For a PID controller with proportional gain Kp, Integral gain Ki and Derivative gain, Kd, transfer function of the controller is[4]

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s$$

Fig. 4 shows the PID control system model of the 3-tank plant. The PID controller is auto tuned in SIMULINK with Kp=7.2434, Ki=0.36925, Kd=35.1959.

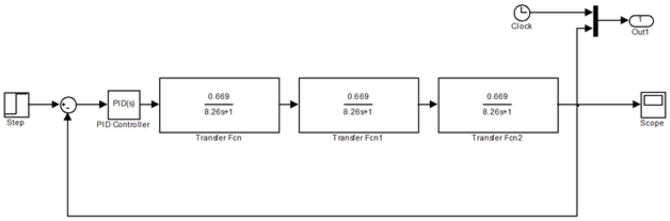

Fig. 4: PID control system block diagram

2.3.2. Fuzzy Controller model

The conventional Fuzzy controller uses membership functions for input and output. The inputs to the controller are basically error, e(t) and change in error, de(t). Rules based on experts knowledge is set in the controller to get the output for a given input.

Membership function of input and output

The membership functions used are triangular membership function in the range -1 to +1 for both input and output.

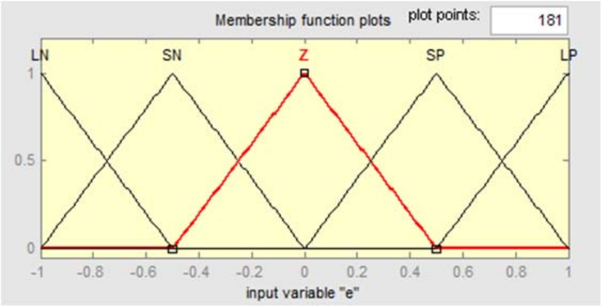

Fig. 5. Membership function (Error)

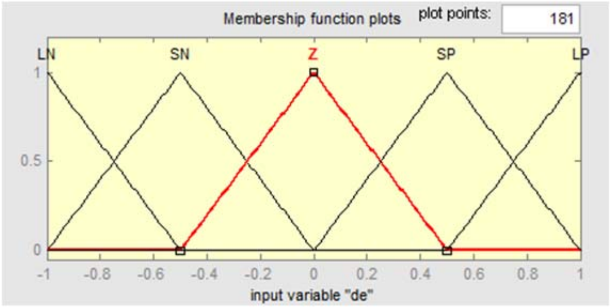

Fig. 6: Membership Function (Change in Error)

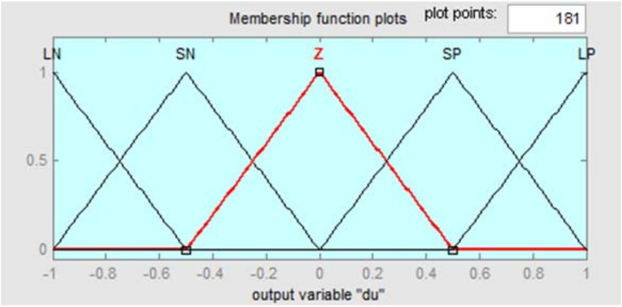

Fig. 7: Membership function (Output)

Rules

The linguistic variables used for the membership functions are LN (Large Negative), SN (Small Negative), Z (Zero), SP (Small Positive), LP (Large Positive) [5, 6]. Output rules are shown in Table1.

Table I: Fuzzy Rules

		e				
		LN	**SN**	**Z**	**SP**	**LP**
de	LN	LN	LN	SN	SN	Z
	SN	LN	SN	SN	Z	SP
	Z	SN	SN	Z	SP	SP
	SP	SN	Z	SP	SP	LP
	LP	Z	SP	SP	LP	LP

Simulink model

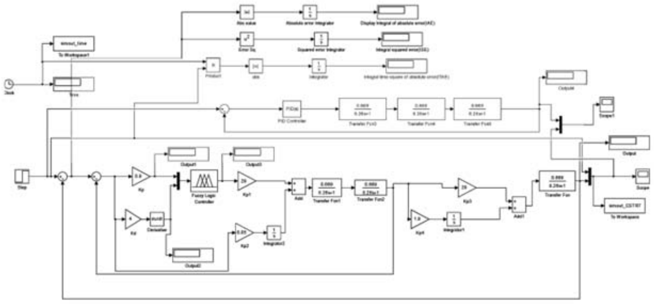

Fig. 8: Simulink model using fuzzy PD-I controller

3. RESULTS

The comparison of PID tuned output and Fuzzy PD-I output after tuning is shown in Fig. 5 where the rise time with fuzzy PD-I has less rise time, no peak overshoot and lower settling time as compared to the PID output. Therefore, we can draw the conclusion that the PD-I controller designed give better output.

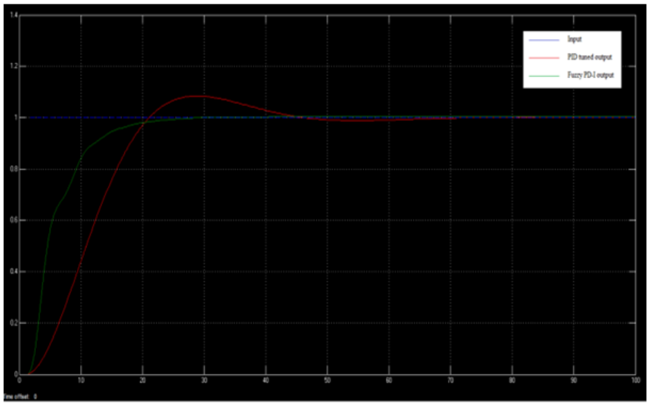

Fig. 9: Fuzzy PD-I and PID tuned output curve.

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